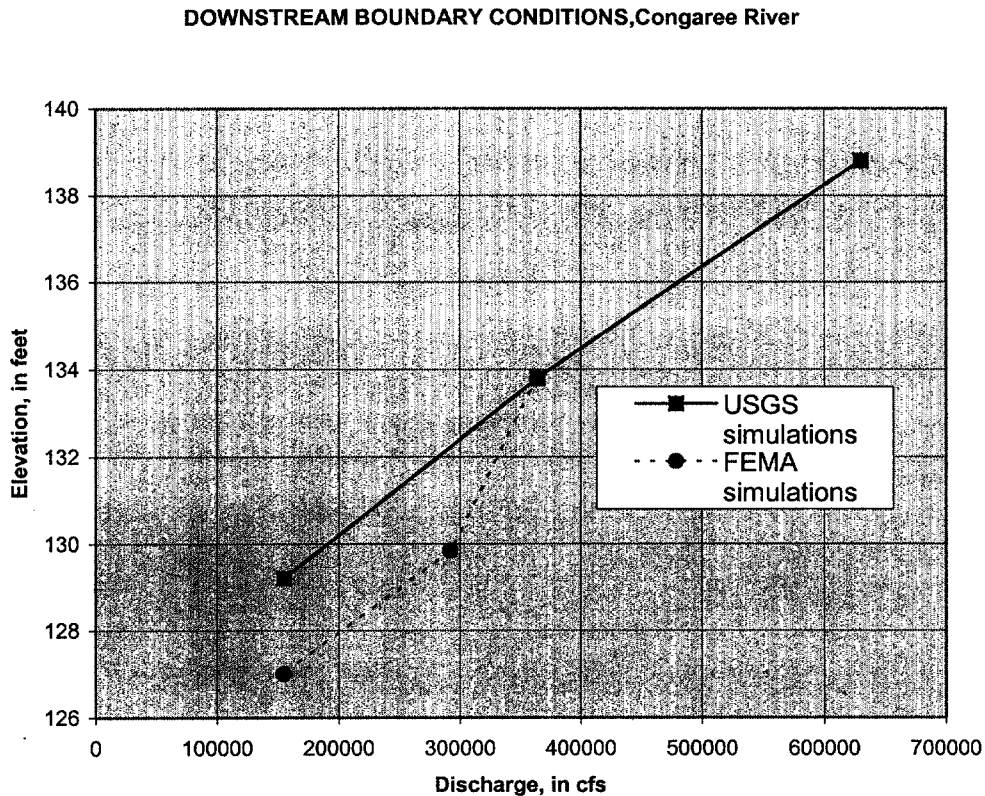


***USGS Review Comments Regarding the Hydraulic Models Used for the
Appeal Resolution for Congaree River in Richland and Lexington
Counties, SC***

The FEMA document above was reviewed by Janice M. Fulford (Office of Surface Water) and Larry R. Bohman (Southeastern Region) of the U.S. Geological Survey for technical/editorial clarity and accuracy. The following comments are submitted to the National Park Service for their consideration:

1. The downstream water surface elevations (boundary condition) used for the 1976 flood calibration of the RMA2 model and for the one percent probability flood simulations appear to be in error. The last two sentences on page 17 of the FEMA report indicate that an elevation of 129 feet was used in previous USGS modeling of the 1976 flood because model limitations at the time precluded a convergent model using an elevation of 127 feet. Neither the 1981 USGS report (OFR 81-1184, Lee and Bennett) nor the 1990 USGS report (WRIR 90-4056, Schuck-Kolben and Benedict) makes reference to any problems with model convergence. An observed elevation of 127 feet for the 1976 flood was indeed measured at a staff gage on the Congaree River near Cayce (station no. 02-169603). This gage is located at the Eastman Kodak Company plant nearly 2 miles downstream of the two-dimensional model boundary. When a flood of 155,000 cfs at an elevation of 127 feet is projected upstream from sta. 02-169603 using a one-dimensional step backwater model, an elevation of 129.2 ft is obtained at the two-dimensional model boundary. All the water-surface elevations used in the USGS modeling studies at the exit flow boundary were computed by routing each simulated flow (155,000 cfs, 364,000 cfs, and 630,000 cfs) upstream from sta. 02-169603 to the downstream boundary of the RMA2 model using a one-dimensional steady flow model. As can be seen in the graph of flows and downstream water-surface elevations used in the USGS and FEMA studies (figure A, below), the elevations used in the FEMA document study for simulated flows of 155,000 cfs and 292,000 cfs are nearly 2 feet lower than they should have been.

Figure A. – Graph of elevations used by FEMA and USGS for the downstream boundary of the two-dimensional flow models for the Congaree River.

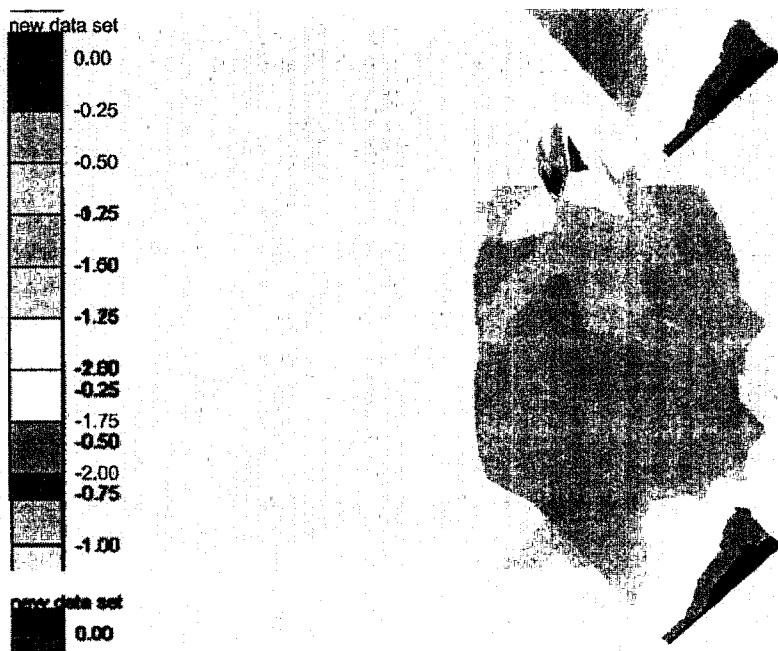


2. The verification of the RMA2 model for Lexington County for the 1976 flood was run using 129.2 ft at the downstream flow boundary. Using higher water-surface elevations at the downstream flow boundary generally result in the RMA2 model computing higher water surfaces. The differences between the measured water-surface elevations and the modeled water-surface elevations for a downstream elevation of 129.2 ft are similar in magnitude to the differences computed using the results computed with 127.0 ft. Table A below lists the differences with the measured values. Figure B shows the difference between the water surface computed for the 127.0-ft and 129.2-ft boundary elevations. The largest differences in computed water-surface elevations are near the downstream flow boundary. A careful calibration of the roughness values for the Lexington County RMA2 model for the 1976 flood would likely result in a better fit of the measured data. Because the RMA2 runs for the one percent flood and the 1908 flood are based on the verification results and because the HEC2 model is calibrated using the RMA2 results, all of the RMA2 and HEC2 results will be affected by any changes made to the Lexington County verification RMA2 model of the 1976 flood.

Table A. -- Difference in feet between measured and computed water-surface elevations for different RMA2 downstream boundary water-surface elevations for the 1976 flood simulation. [DS, downstream; ft, feet]

Location Number	127.0-ft DS boundary	129.2-ft DS boundary
1	-0.71	-0.51
2	-0.43	-0.06
3	0.38	0.89
4	-0.22	0.26
5	2.55	3.12
6	2.47	3.11
7	-0.55	0.651

Figure B.-- Water elevation differences for simulation of 1976 flood between a downstream flow boundary of 127.0ft and 129.2ft



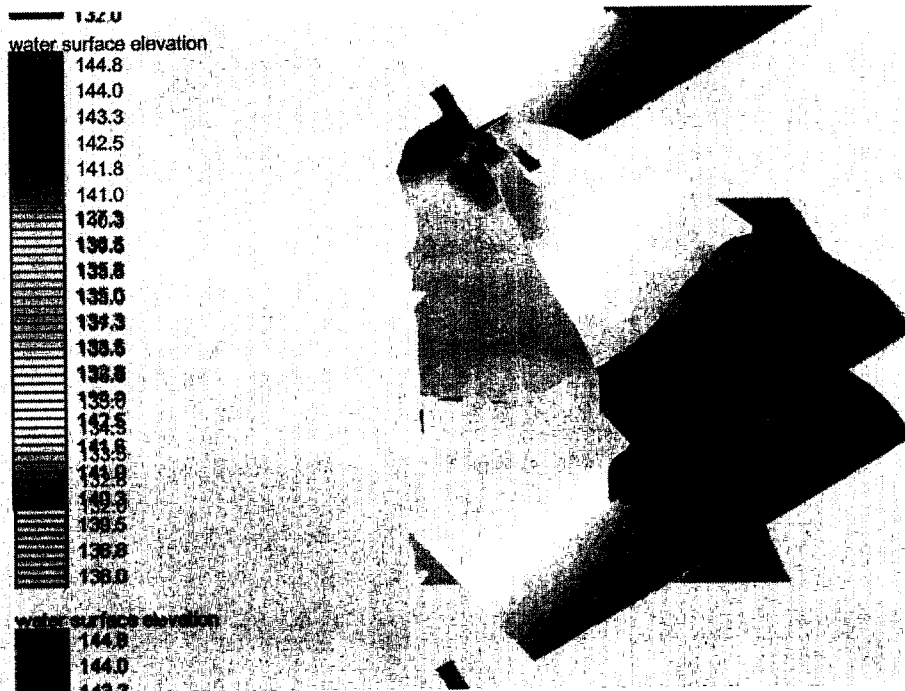
3. Additionally, the two-breach simulation for the one percent flood was re-run using 131.84 ft at the downstream flow boundary. Figure C shows the difference between the water surface computed for the 129.84 ft and the 131.84 ft boundary condition. The largest differences are near the downstream flow boundary. Differences from 2.00 to 1.50 ft exist south of the I-77 crossing on the Richland County side and from 2.00 to 0.25 ft exist south of the I-77 crossing on the Lexington County side. Generally, an increase in the downstream boundary water-surface elevation affects the water-surface elevations downstream of the I-77 crossing more than the elevations computed upstream of the I-77 crossing.

Figure C.-- Water surface elevation differences for the two breach, one percent flood simulation using a downstream water-surface elevation of 129.84ft and 131.84ft.



4. We concur that if breaching or overtopping of the Manning Dike occurs, that significant flow will take place on the Richland County side of the dike. As part of our review, the RMA2 model mesh was modified for a very large failure of the dike in the north section of the levee. This run supported the FEMA report conclusion that a significant portion of the one percent flood flow will take place on the Richland County side of the dike. Water-surface elevations computed using the modified mesh are shown in figure D below.

Figure D.-- Water-surface elevations computed for a very large breach of the dike in the northern end of the Manning's dike using a downstream flow boundary of 131.84 and a discharge of 292,000 cfs.



5. The RMA2 grid resolution used to model the study area is outdated and is a remnant of computational constraints from earlier versions of the two-dimensional modeling studies. The change in water-surface elevations computed with a more detailed grid may or may not significantly change the results, but it could be identified as a possible shortcoming of this modeling effort. A more refined grid would allow the computed water surface to warp more freely in the modeled area and result in smaller numerical errors.
6. The downstream flow boundary conditions used in the HEC2 simulations are not discussed in the FEMA document. From the HEC2 files it was determined that energy slope was used for the boundary condition. Boundary conditions have a large influence on the water-surface elevations computed by a flow model. How they are determined should be discussed in the report. It is not clear whether the energy slopes used are arbitrary, carefully chosen on the basis of fitting the HEC2 model to the RMA2 results or chosen on the basis of some other analysis.
7. The ineffective flow areas were determined using RMA2 simulations of the 1908 flood of 364,000 cfs with flow through both the Richland and Lexington County meshes. Areas in the RMA2 simulation with computed velocities of less than or equal to 1 ft/sec were removed by FEMA from the HEC2 cross sections. No explanation was given for why 1 ft/sec was selected as the cutoff velocity and this arbitrary velocity seems a bit high. Also, the extent of the ineffective flow area computed from these analyses might be a product of the contouring program used by FEMA. It is not clear why the 1908 flood was used instead of the one percent

flood. The one percent flood is used to compute the floodway with the HEC2 model. The one percent flood discharge should give a better estimate of the ineffective flow area for the one percent flood than some other flow. Using a RMA2 model that more closely resembles the flood plain conditions modeled in the HEC2 simulations (ineffective levee, I-77 highway crossing and current land use patterns) should also improve the estimate of ineffective flow area used in the HEC2 model.

8. The HEC2 runs were made for the one percent flood with the Manning's dike intact and with the Manning's dike ineffective. When the one percent flood is constrained to the right (Lexington County) side of the flood plain, higher velocities are computed for the Lexington County side in the RMA2 model. This would have decreased the ineffective flow areas computed by the RMA2 model for the HEC2 model on the Lexington side of the floodplain and may have changed the results of the HEC2 computations for the one percent flood with the dike intact.
9. Based on table 6 in the FEMA report, the elevations obtained via HEC2 seem to be negatively biased when compared to measurements at the Columbia stream gage. This indicates that the HEC2 simulations underestimate the computed water-surface elevations at least in the reach near the Columbia gage (Table B).

Table B. -- Difference in feet between measured and HEC2 computed water elevations at the Columbia gage (sta. no. 02-169500).

Year	Discharge, in cfs	Difference, in feet
1908	364,000	-0.5
1928	311,000	-0.33
1929	303,000	-0.41
1916	272,000	-0.65
1912	256,000	-0.83
1936	231,000	-1.01
1976	155,000	-0.21
1964	142,000	-0.31
1990	135,000	-0.27

10. Some of the model input and output files provided for review were not the final ones used to support the FEMA document. We could not find any HEC2 runs in which 155,000 cfs was used for the discharge (calibration runs). Further, the comments included in those HEC2 data files were insufficient to allow us to follow the strategy as explained in the text of the FEMA document. Many of the

HEC2 output files provided for review contained error messages indicating that tolerance limits for conveyance ratios were exceeded, possibly indicating the need for additional cross-sectional definition. In another example, the RMA2 files provided were coded with Manning's "n" values of 0.030 for the main channel instead of the 0.038 cited in table 3 of the FEMA document. Thus, we had to change boundary conditions before attempting model runs to verify FEMA results.

11. A good map in which both the RMA2 model domain and the HEC2 cross sections were plotted would have been helpful. One case where such a map would have helped to avoid confusion is in examining the first row of information in table 5. If HEC2 cross section "A" is the downstream study limit for the RMA2 model, why are the results (water-surface elevations) different? In another example, the last row of information in table 4 indicates that the observed elevation at sta. 02-169603 is different than the starting elevation used in the HEC2 model. No explanation is given as to why this difference exists.
12. Table 4 in the FEMA report lists many location numbers. None of these location numbers are shown plotted on any figure in the report. Fortunately, the reviewers had access to the USGS 1981 report that shows most of the locations on plate one of the report. A map showing the locations of the numbers is needed to properly explain the table to the reader. Location 8 is upstream of all the other locations. It is confusing to insert it in the location of the table as shown.
13. Table 5 of the FEMA report-- The locations of these points in this table are impossible to reference using figures provided within this document.
14. Tables 5 and 6 of the FEMA report-- The footnotes in these tables reference results from the files "Finalhgh.018" and "Finalflow.018." We were not provided these files.